

# Measuring the Impact of Human Factors Interventions

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## ABSTRACT

Human Factors interventions compete for resources in an airline maintenance environment. Senior managers ask for measures to show how human factors interventions can affect the "bottom line". They want to know the return on investment in human factors. This paper looks at research, in progress, that has the goal of reducing installation errors in heavy aircraft maintenance. Working with two large carriers and a large repair station, the project has established the goal of a 50 percent reduction in selected error categories. The paper summarizes the rationale for the research and the current state of the research project. We describe the data collection methods, the plans to develop interventions, and the challenges expected as we quantify the return on investment.

## INTRODUCTION: RETURN ON INVESTMENT IN MAINTENANCE HUMAN FACTORS

Since 1988, the FAA Office of Aviation Medicine Human Factors In Maintenance research program has conducted extensive applied research in airline maintenance environments. The website ([www.hfskyway.com](http://www.hfskyway.com)) offers over 10,000 pages of research reports and example software packages that offer guidance to the industry. Among those are *The Human Factors Guide for Aviation Maintenance* (1) and the *Maintenance Resource Management Training Handbook* (2). The research program has offered 13 Symposia on maintenance human factors, most recently in cooperation with Transport Canada, and the CAA of the United Kingdom. The proceedings from these conferences are also at the website.

The Research and Development described above has been widely accepted and applied to airline settings. The next step in the maturity of maintenance human factors programs is to justify them based on cost. Most managers believe the programs are good and continue to invest in them. However the cry "show me why" is

reoccurring. This project, therefore, will not only identify ways to reduce error but also it will show the cost impact of such error reduction.

At an initial glance, the non-economist can have a straightforward view of return on investment (ROI). It appears to be easy. The MBA might say quickly that ROI is "...net income divided by total assets..." (3), or..."net earnings over total assets...(4). First, determine the cost of the investment and merely compare that to the return. That return can be money made or money saved.

While the ROI ratio seems simplistic, the real world of airline maintenance can complicate the ROI calculation. Further, the sometimes-imprecise measurement of human factors interventions also exacerbates the complexity of such calculation. It is quite common to demonstrate the effectiveness of a human factors intervention in a university psychology laboratory, where most variables are controlled. However the numbers of variables that affect airline maintenance make such measurement a very difficult challenge at best. We expect to meet that challenge with excellent industry partner cooperation and a full knowledge of the complexity of the problem.

Dietrich Dorner, in the *Logic of Failure* (5), describes the fictitious West African tribe of seminomads called the Moros. His discussion of the Moros illustrates that one change to an organization/culture often has immense and sometimes immeasurable affect on others parts of the organization. In his book he describes a simulation in which the amount of rainfall is varied. This not only affects crop growth but impacts transportation, the economy, food consumption habits, and the list goes on.

Similarly, one change to a maintenance organization has an impact that can ripple. Say, for example, the organization decides to provide small hand-held computers to ensure that the technician has current technical manuals and job cards at the worksite. This

change affects such things as work card design, work procedures, sign-off legacy documents, amount of training for the technician, need for licensing of certain technicians, access of information by the inspector, wiring of the maintenance work site for digital communication, creation of a local network for the hand-held computers, and the list can go on and on.

The example above may result in a reduction of errors, a reduced time to task completion, or a requirement for fewer workers with less qualification. If that happened, would the change be a result of the computer, the new work card design, the increased training, or the corporate consciousness on use of work cards? Or, at the same time did the airline replace the fleet of oldest aircraft with state-of-the-art new airplanes that do not require as much maintenance? This example shows that the measurement is difficult.

In a recent meeting at Northwest Airlines Technical Operations, David Marx, a Senior Human Factors Consultant to the Quality Assurance department, grabbed a handful of change from his pocket and placed it on the table. Using an ascending denomination of four coins he asked, "If each of these coins represents a specific human factors intervention, which one would you select?" Of course his question begged the answer as to the expected impact of each of the interventions. If the low cost intervention has a high impact then the choice is easy. But that is often not the case. The selection complicates when you choose more than one. The impact of the various interventions becomes interwoven and thus it is difficult to assign a ROI value to specific interventions. The economic analysts at the meeting offered to write a complex predictive model to answer such questions. However the rationality of such a decision prompted the "tongue-in-cheek" remark that the ROI of creating the model was likely to be too low.

The research team is comprised of a mix of engineers and psychologists. However, we have already started consulting with the financial personnel from the airline and associated companies. The financial consulting activity will continue throughout the project. The remainder of this preliminary report describes where the project stands and how we approach the expected challenges of measuring the impact of human factors interventions.

## RESEARCH RATIONALE AND DEFINITIONS

Installation error rates high as one of the most common human errors in maintenance. Boeing Airplane Company, General Electric Engines, United Technologies, and studies from the CAA in the United Kingdom all rated incomplete installation at the top of the error list. Therefore an attempt to reduce such error is a likely and reasonable goal for a human factors research study. In order to delimit the challenge the research team decided to focus on those installation errors committed at final assembly, during heavy maintenance.

Installation error, for the purpose of this study was defined as:

***"Any misinstallation that may result in a reliability or safety effect (that is discovered) downstream."***

As the project evolved the team decided that the extensive investigations should be focused on errors found within the first 21 days of aircraft delivery to flight operations. Such errors have the potential to cause delays and cancellations, which are significant cost drivers. The numbers of errors discovered in the first 21 days is also a good industry standard measure of the overall quality of the maintenance.

This project is somewhat unique in that the interventions chosen to address errors have not been chosen beforehand. In fact, the primary focus of the project lies in the data collection and analysis phase. The choice of interventions will be driven by the data collected in the initial phases of the project as well as by forecasts of probability and costs of success.

With the goal of reducing selected installation errors by 50 percent other specific deliverables were defined. As usual with the FAA aviation maintenance human factors research, the team vowed to have products and reports that can be used throughout the industry. Therefore deliverables include, but not be limited to the following:

1. List of interventions matched to installation errors.
2. Report documenting the project and the quantifiable success of the error reduction.
3. Report discussing Return of Investment for human factors interventions in aviation maintenance.

The research project commenced in April of 1999 and span a 24-month period. The level of cooperation and activity of the cooperating industry partners drives the schedule. Thus far, that commitment and cooperation has been very good.

## DATA COLLECTION

Boeing Commercial Airplane Company developed the Maintenance Error Decision Aid (MEDA) (7)) in the mid-nineties and has provided training to over 120 airlines worldwide. The MEDA system and airline-specific derivatives are being used as the guide to conduct investigations on each installation error incident. The system then helps the team to determine if installation error was a problem and to identify possible root causes.

Portions of the Boeing MEDA training were used to ensure that all investigators were standardized on the data collection methods.

## CHALLENGES AND PLANNED SOLUTIONS

The remainder of this paper discusses the expected challenges of the project and offers our plan to meet them. In some case, the implementation plans are in effect or completed. The challenges are not necessarily listed in the order of importance since such order changes over the course of the project. We address the example challenges listed in Table 1.

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|---|
| <b>Identifying Optimal Industry Partners</b>              |
| <b>Proprietary Data</b>                                   |
| <b>Cultural Differences on the Team</b>                   |
| <b>Time Commitment for Error Reporting</b>                |
| <b>Identifying Optimal Interventions</b>                  |
| <b>Establishing Costs for Interventions</b>               |
| <b>Valuing Cost Savings and Matching to Interventions</b> |

**Table 1: Example Challenges**

### Identifying Optimal Industry Partners

Industry partners are the key component to a quality applied research project. Without their full cooperation, the project can become an academic exercise that results in a technical report with limited “real-world” usefulness.

We attempted to find industry partners with a demonstrated commitment to human factors in maintenance. That commitment is usually evidenced by such characteristics as having personnel who have specific dedicated job responsibilities for maintenance human factors. Such organizations usually have a formal process for error reporting and a formal discipline system complementary to the error reporting system. These aviation maintenance organizations always have a strong managerial commitment to the investment in maintenance human factors.

We wanted to ensure that the industry partners had diversity among their organizations. That diversity could include the existence of a labor organization; the geographical dispersion of the maintenance facilities; the size, age, and make-up of the fleet; and the amount of 3rd party maintenance sold or purchased. We also believed that it was important to include airlines as well as repair stations.

The aviation industry was very anxious to commit resources to the project. Many airlines and repair stations volunteered to participate. In fact, the number of willing participants exceeded the scope of the planned project. Therefore, we selected the team based on their expert knowledge of error investigation and the number of error investigations they had completed prior to the project. Airline participants were also selected based on

their positive past cooperation with the FAA research program. Further, we selected participants based on some geographical considerations that would control project costs.

Based on these and other considerations, we are extremely pleased with the potential of the three partner organizations.

### Proprietary Data

The FAA-sponsored researchers always have a serious responsibility to protect the proprietary data of their industry partners. This responsibility requires us to be very selective about how the data is shared with other partners, the industry at large, and even the FAA. The research team has no regulatory affiliation with FAA thus any reporting to FAA would be the responsibility of the airline partner.

Management from the participating companies made it clear that they are willing to share the generic information that contributes to safety and even to efficiency. The senior managers made it clear that they fully expected the co-participating partners to be open with their data. The industry partners expected the FAA consultants to add value to the project by organizing the project, analyzing the data, offering proven human factors interventions, and by respecting the private nature of selected error and financial data and models. Past performance of the FAA research team, since 1988, has never violated this semi-fiduciary responsibility.

### Cultural Differences on the Team

There are two large carriers and one large repair station participating in this project. The cultures are different. However, all three companies at the high senior level are committed to this project and to reducing human error in maintenance.

In order to share goals and overcome cultural differences we intend to have frequent meetings, often by conference calls. The use of standard definitions and very similar MEDA-like forms is helping to standardize our thinking and ensure that our approach to the research is similar.

One significant difference between the industry partners work force is that one of the three has formal labor union representation. While that difference changes some of the rules of communication there has been a very positive involvement of all levels of labor at all three industry partners.

The formality of the corporate discipline policy has an effect on error reporting. The local FAA approach to discipline of self-reporters also affects the reporting

culture. The combination of an enlightened company management that truly works together with the company's FAA Principal Maintenance Inspector is the ideal situation.

**Time Commitment for Error Reporting**

We anticipated that it would be problematic to expect voluntary error reporting to provide sufficient information to identify the best opportunities to reduce installation error. Therefore we select incidents resulting from problems discovered after the aircraft is delivered to service. In these cases the situation is often of greater significance thus prompting management action. This action manifests itself in a maintenance error investigation.

The industry partners estimate that this level of reporting and investigation is already a significant step in error reduction. One of the airlines estimates that they will conduct 150-200 error investigations in the first 60 days of the data collection period. Assuming that an investigation can take from 2-4 hours per incident, the time commitment for investigators ranges from 2-5 person-months in a very short period. Any size maintenance organization is affected by such a large effort. We recognize that other priorities will often tax the error investigation team. Therefore we enter this project with the realization that fixing airplanes comes first, the research project is second. Fortunately the research project contributes to the quality and efficiency of the maintenance over the long run.

Each participating industry partner has dedicated personnel to this project. That commitment is essential as the project proceeds.

**Identifying Optimal Interventions**

The researchers work with the airlines to identify interventions matched to the identified errors. We expect that the project will encourage the industry partners to formalize their response to error situations. Often the best solution is under your nose and the researcher merely helps you find it.

The identification of interventions extend beyond the limits of the individual industry partner or the team. The researchers have the responsibility to elicit plans from such documents as the *Human Factors Guide for Aviation Maintenance* and other such documents from the 12-year FAA aviation maintenance human factors research program and from other sources and industries. The nuclear power industry, for example, has numerous human-centered documents to promote safe and efficient maintenance work.

The team will remain aware of all the social, political, regulatory, financial, and technical issues that may be associated with any planned interventions. The partnership between the industry and the FAA

researchers will ensure that the “pie in the sky” solutions are not suggested.

An important deliverable from this project will be an organized listing of interventions matched with the error categories. This deliverable will be a form of a checklist that can be matched to many of the root causes likely to emerge from MEDA investigations. Such a checklist can be combined with an automated MEDA system to automatically provide intervention advice to MEDA users.

**Establishing Costs for Interventions**

This challenge goes beyond establishing the cost of the interventions. This challenge also forces the team to better understand the manner in which airlines calculate ROI. Table 2 is an example of the questions that are being used in the discussions with airline financial personnel. One airline Finance Director has been very helpful in not only the answers but also by providing the “right” questions to ask.

We expect that it is relatively straightforward to establish cost of interventions. For example, if a work area needs different lighting it is easy to calculate the cost of such change. The same holds true if a ramp space needs better signs, or if technical documents need to be changed. Interventions, like training, are more difficult to estimate but certainly the airline partners are quite savvy about such estimates.

We plan to take Systems Engineering approach to estimating the cost of interventions. Where job task analysis is necessary we will do so. We will calculate the cost of people’s time and the materials necessary to effect the intervention.

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|---|
| <b>How does your airline calculate ROI in Technical Operations?</b>                                     |
| <b>At what dollar investment level must a ROI analysis be completed?</b>                                |
| <b>What is the ROI target necessary to justify an investment?</b>                                       |
| <b>How formal is the follow-up tracking on each Technical Operations investment?</b>                    |
| <b>How does expected safety improvement receive value in the ROI?</b>                                   |
| <b>What model is used to estimate extra days in the shop during heavy maintenance?</b>                  |
| <b>What is the average cost of post maintenance errors discovered after the A/C is back in service?</b> |

## How does the Time-value of money affect the ROI analysis.

### Table 2: ROI Questions for Discussion

#### Valuing Cost Savings and Matching to Interventions

This presents itself as one of the largest challenges. The reason is that this task may be more of a financial exercise than an engineering or psychology effort. However, at the current time the approach is the following.

In order to determine savings, we must first place a specific financial value on the cost of the error or the category of errors. This costing should include the labor time, material costs, delay costs, and all of the other costs of a broken aircraft. Currently airline technical operations departments are aware of the cost of a delays and cancellations. These numbers will be useful input to calculate the cost of an error.

We have already established that it is quite possible to place a cost on the intervention. Therefore, in a simple way, we would only need to compare the costs of the intervention to the cost savings of reduced error over some time period. The time-value of the money spent on the intervention must be calculated to determine the true ROI.

We recognize that the greatest challenge here is associated with multiple interventions. We must determine the interaction of the interventions to determine which has the greatest value. The current plan is to try to isolate each intervention as it maps to select errors. We will then monitor these errors and work with the airline financial experts to calculate cost savings and ROI.

#### CONCLUSIONS

The research is well underway. Senior management, from the three industry partners, has given a firm commitment to participate in this project. We have a committed team of researchers and industry partners working together. We have identified the data collection instruments and embarked on data collection. We have a good plan on how to approach data analysis and to identify good interventions. Operational schedules have presented challenges to the timetable but that is expected in real-world data collection. Delays have not created insurmountable difficulties.

It is premature to form conclusions at this point in the research. However, reasonable speculation is appropriate. We expect to show a large decrease in installation error by determining the root cause of each incident and then proposing a "fix" that can be implemented at the work site.

We expect to show that there is a demonstrated return on the investment in human factors interventions. We plan to create a model for assessing ROI for additional human factors interventions.

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